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Characteristics of Wastewater Taken from A Pool Water System: Analysis of Physicochemical and Phytotoxicological Parameters in Terms of Recyclability

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Abstract: The presented research focused on the possibility of reusing washings from rising filters for the maintenance of greenery. For this purpose, a physicochemical assessment of the washings was carried out, the washings were subjected to a preliminary treatment - dechlorination and sedimentation. Then, washings solutions (5 - 100%) were prepared in water matrices: deionized water, tap water, and rainwater, and selected physicochemical parameters were checked again. The ecotoxicological assessment was performed with the use of selected plant indicators: *Lemna minor*, *Sinapis alba*, *Lepidium sativum*. The stimulating effect of the addition of washings on the germination of *S. alba* and *L. sativum* was observed. This phenomenon depended on the water matrix in which the washings were dissolved and on the concentration of the washings. Moreover, *L. minor* was an organism with a higher sensitivity to the ingredients contained in the washings. It should be noted that the physicochemical quality of the washings was subject to changes during the study, which had a major impact on the results of the phytotoxicological assessment.

Keywords: swimming pool; washings; ecotoxicology; circular economy; closed circuit; recycling

1. Introduction

Each public swimming pool must have its own pool water treatment circuit. Circuits of this type operate as closed systems in which the water is continuously treated and disinfected. Water splash losses are continuously replenished with tap water that normally feeds the circuit [1]. The process commonly used for the treatment of swimming pool water is filtration through porous beds (sand, sand with hydroanthracite, zeolite, with filter glass, etc.). Regardless of the bed structure and filter material, each bed must be periodically cleaned - rinsed. In the case of pressure filters supported by contact coagulation, the beds are rinsed with a stream of air and water (from the equalizing tank) in the opposite direction to that of normal filtration (backwashing). As a result, a stream of wastewater - washings, rich in impurities washed out of the bed, suspensions, and flocs after the coagulation process, is obtained [2,3]. The washings are usually discharged directly to the sewage system. Systems for the recovery of heat from washings are used increasingly often, less often they are recycled or used in toilet bowls. It should be noted that to carry out a proper rinsing process, the DIN standard recommends the use of 4 - 6 m^3 for each m^2 of filter bed. In the case of larger facilities, this generates large volumes of washings, which have the potential for re-use [4,5].

The aim of the research was to analyze the possibility of using the washings to maintain greenery during periods of rainfall deficiency, thus limiting the consumption of tap water. As part of the analysis, the physicochemical quality of the collected washings was assessed, enriched with the phytotoxicity assessment.

2. Materials and Methods of research

2.1. Subject of study

The subject of the research were washings samples taken from the swimming pool circuit. The circulating water is purified by a multi-layer filter bed (quartz sand - hydroanthracite). The filter bed was rinsed every 24 hours, each time the facility was closed. There are three identical beds in circulation, the single rinsing of which generates over 30 m^3 of washings. Washings samples were taken from the settling tank during the rinsing of the beds into plastic containers with a capacity of 10 liters. The next day, in the morning, physicochemical analyses of the washings were carried out. The washings were subjected to the sedimentation process for 24 hours to reduce the content of total suspended solids. Then, solutions containing washes with a concentration of 5, 10, 25, 50, 75, 100% were prepared in water matrices: deionized water, tap water, rainwater. Washings samples were collected for 10 weeks, physicochemical and ecotoxicological assessments were performed for each of the prepared solutions.

2.2. Physicochemical analyzes

The assessment of the quality of the washings and their solutions included the analysis of physicochemical parameters. Selected parameters are presented in this work. The pH was determined by the potentiometric method (Multiparameter meter inoLab® 740/WTW, Measuring and Analytical Technical Equipment, (Wroclaw, Poland)). The total suspended solids (TSS) content was determined by the method of filtration through glass fiber filters [6]. The free and total chlorine and potassium concentrations were determined colorimetrically using cuvette tests. Total nitrogen, cyanuric acid, phenol index, aluminum, chlorides, zinc were determined spectrophotometrically (UV-VIS Spectroquant® Pharo 300, Merck, Dramstadt, Germany). The concentration of total organic carbon (TOC) was determined by catalytic combustion (TOC-L series, Shimadzu, Kyoto, Japan). The presented values are the arithmetic mean with standard deviation (Mean ± SD) of 10 independent samples (Table 2).

2.3. Phytotoxicity assessment

Phytotests with *Lemna minor* were conducted based on OECD recommendations [7]. 8 cm^3 of tested samples were dispensed into threaded vials made of transparent glass with a capacity of 12 cm^3. *L. minor* was placed in the vials, the number of fronds was noted on the day the test was started (day 0). The effect of the analyzed samples on the test organisms was determined based on changes in the 7-day tests. Three repetitions of the test were performed for each of the tested solutions. The tests determined the average specific growth rate from moment time i to j from equation μ_{i-j} [-] (1) and percent inhibition in average specific growth rate I_r [%] according to formula (2) [7]:

$$\mu_{i-j} = \frac{ln(N_j) - ln(N_i)}{t_j - t_i}, \tag{1}$$

where: N_j – number of fronds observed in the test or control vessel at time j; N_i – number of fronds observed in the test or control in vessel at time i; t_i – moment time for the start of the period, t_j – moment time for the end of the period.

$$I_r = \frac{\mu_C - \mu_T}{\mu_c} \cdot 100, \% \tag{2}$$

where: μ_C – mean value for μ in the control; μ_T – mean value for μ in treatment group (washings solutions).

Control samples consisted of deionized water, tap water, and rainwater, respectively, depending on the tested washings solution matrix. Negative frond growth inhibition values mean stimulation of their growth. The samples are classified according to the magnitude of the toxic effect: $I_r < 25\%$ - non-toxic; Ir = 25.1 - 50% - low toxic; Ir = 50.1 - 75% toxic; Ir = 75.1 -100% - highly toxic [8].

The phytotoxicity of the washings and their solutions, using *Lepidium sativum* and *Sinapis alba*, was assessed based on the Phytotoxkit® procedure [9]. 5 ml of test samples were poured on Petri dishes (in triplicate for each test), and then 10 pieces of *L. sativum* and *S. alba* seeds were sown on each of the samples, the plates were placed in a laboratory incubator (Elkon) at a temperature of 25°C. The number of sprouted seeds and the length of the roots were read after 24, 48, 72, and 96 hours. Value of the coefficient relative germination percentage RGP [%] was determined based on formula (3). While relative radicle growth RRG [%] was determined from equation (4):

$$RGP = \frac{G_S}{G_C} \cdot 100, \% \tag{3}$$

where: G_S – the number of germinated seeds in the test sample; G_C – number of germinated seeds in the control sample.

$$RRG = \frac{L_S}{L_C} \cdot 100, \% \tag{4}$$

where: L_C – root length of germinating seeds in the control sample [mm]; L_S – root length of germinating seeds in the test sample [mm].
In this study, the presentation of the results was based on the value of the germination index GI [-], determined from equation (5), and the obtained values were classified based on the values presented in Table 1 [10].

$$GI = \frac{RGP \cdot RRG}{100}, \tag{5}$$

Table 1. Toxicity classification based on the germination index GI [10].

Germination Index Value	Effect
$GI \geq 100$	Growth stimulation
$100 > GI \geq 80$	Non-toxicity
$80 > GI \geq 50$	Moderate toxicity
$50 > GI$	High toxicity

All assays were carried out in triplicate, and the results were expressed as mean ± SD. Means and standard deviation were calculated using the MS Excel statistical package. Student's t-test was used to determine the significance between the analyzed and the control sample. A difference was considered significant if the p-value was less than 0.05 ($p < 0.05$).

3. Results

3.1. Physicochemical assessment

The raw washings (after sampling) were characterized by a high content of total suspended solids of 142.50 ± 59.10 mg/L (Table 2). Attention should be paid to the significant standard deviation from the arithmetic mean, i.e. the differentiated amount of suspension during the test period. Moreover, an increased concentration of chlorine was noted, which made it impossible to discharge the washings directly into the soil. The value of the remaining physicochemical parameters was low to the extent that meant that the washings could be reused [11]. The 24-hour sedimentation process in the Imhoff funnel allowed for a significant reduction in the total suspended solids content (32.50 ± 6.80 mg/L). Moreover, a reduction in the concentration of free chlorine (0.05 ± 0.05 $mgCl_2/L$) was obtained (as a result of free dechlorination), which allowed for an ecotoxicological assessment of washings, while limiting the effect of chlorine as the main toxic factor for plants. Diluting the washings with selected water matrices also allowed reducing the concentration of pollutants in the solutions. It is particularly important to control the concentration of aluminum (the source in the washings are coagulants), which may be a toxic factor for plants (concentration in the raw washings 0.79 ± 0.07 mgAl/L).

Table 2. Physicochemical quality of washings and their solutions with a matrix: rainwater.

Parameter	Share of washings in rainwater (Mean ± SD)							
	Raw washings	0%	5%	10%	25%	50%	75%	100%
pH, -	6.97 ± 0.16	7.03 ± 0.23	7.03 ± 0.23	7.05 ± 0.14	6.95 ± 0.22	7.06 ± 0.13	6.99 ± 0.15	6.94 ± 0.14
TSS, mg/L	142.50 ± 59.19	14.50 ± 3.27	15.33 ± 3.14	15.33 ± 2.66	16.00 ± 3.03	18.00 ± 2.28	20.33 ± 3.27	32.50 ± 6.80
Free chlorine, $mgCl_2/L$	0.72 ± 0.15	0.00* ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.05
Total chlorine, $mgCl_2/L$	1.70 ± 0.23	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.05	0.05 ± 0.09	0.11 ± 0.04
Total nitrogen, mgN/L	7.65 ± 0.61	8.42 ± 0.97	8.58 ± 0.80	8.80 ± 1.12	7.79 ± 0.83	7.58 ± 0.44	7.63 ± 0.45	7.60 ± 0.66
Cyanuric acid, $mgC_3H_3N_3O_3/L$	3.50 ± 0.40	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.54 ± 0.40	1.59 ± 0.39	3.30 ± 0.52
Phenol index, mgC_6H_6O/L	0.42 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.17 ± 0.04	0.24 ± 0.07	0.35 ± 0.05
Aluminum, mgAl/L	0.79 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.13 ± 0.05	0.18 ± 0.04	0.78 ± 0.05
Chlorides, mg/L	187.67 ± 18.58	83.00 ± 17.32	132.50 ± 17.17	134.33 ±17.31	142.83 ± 19.69	153.00 ± 16.70	151.67 ± 20.17	182.33 ± 18.14
Zinc, mg/L	0.00	0.76 ± 0.35	0.67 ± 0.33	0.63 ± 0.31	0.61 ± 0.19	0.40 ± 0.15	0.10 ± 0.12	0.00 ± 0.00
TOC, mgC/L	9.91 ± 1.00	0.42 ± 0.66	0.56 ± 0.64	0.61 ± 0.64	0.84 ± 0.82	2.12 ± 0.58	3.43 ± 1.06	9.40 ± 0.98

3.2. Phytotoxicological assessment

Depending on the concentration and the indicator organism used, either stimulation or inhibition of plant growth was observed. It should be noted that two independent 4-point scales were used for the classification of phytotoxicity (Table 3). For *Lemna minor*, there was low toxicity of the 100% washing solution in all analyzed matrices as well as for 75% washing solution in deionized water (inhibition of frond growth was 39.77 ± 3.71% and 31.18 ± 4.49%). *L. mino*r frond growth stimulation was noted in samples with 10% washing solution (matrix: deionized water); 5, 25 - 75% washing solution (matrix: tap water), and partially from samples of washing solution with a concentration of 10, 25, 75% (matrix: rainwater). *Sinapis alba* and *Lepidium sativum* turned out to be less sensitive to the ingredients contained in the tested washings. None of the tested samples was toxic to plant growth. Moreover, for tests with *L. sativum* in washing solution with a concentration range from 5 to 75% (all matrices), stimulation of plant growth was observed (Table 3).

4. Discussion

The reuse of wastewater is an important aspect of water supply in areas with water shortages. However, the negative impact that may be associated with the migration of heavy metals, increased soil salinity, or phytotoxic effects should be considered [12]. The washings, although treated as wastewater, are of a much better quality, so can be reused. However, attention should be paid to the remains of coagulants and post-coagulation sludge in the washings. Since aluminum coagulants are commonly used in water treatment in swimming pool facilities,, the presence of aluminum in the washings may contribute to growth inhibition (especially of roots), damage to the plant structure, or disturbance of nutrient uptake by plants, especially with longer irrigation with washings [13-15]. In short-term tests, it was shown that raw washes (100% solution) can have phytotoxicological potential, which was observed in the 7-day *Lemna minor* biotest. No toxic effect was observed in short germination and growth inhibition tests (96 hours), which may be related to both the shorter duration of observation and the lower sensitivity of *L. staivum* and *S. alba* to washing components, including aluminum compounds [15].

Table 3. Phytotoxicity of washings solutions and classification of toxicity.

Matrix	Share of washings in matrix, %	I_r *Lemna minor* (Mean ± SD), %	Toxicity classification	GI *Sinapis alba* (Mean ± SD), -	Toxicity classification	GI *Lepidium sativum* (Mean ± SD), -	Toxicity classification
Deionized water	5	10.63 ± 7.27	Non-toxic	118.30 ± 10.24	Growth stimulation (5-57%)	127.18 ± 8.65	Growth stimulation (5-75%)
	10	-7.82 ± 3.71	Growth stimulation	118.42 ± 11.14		125.55 ± 11.45	
	25	1.92 ± 4.76	Non – toxic	102.52 ± 9.87		121.04 ± 8.98	
	50	9.04 ± 7.65	Non -toxic	114.42 ± 10.68		142.33 ± 12.33	
	75	31.18 ± 4.49	Low – toxic	135.83 ± 12.32		136.93 ± 12.33	
	100	39.77 ± 3.71	Low -toxic	86.62 ± 8.75	Non-toxic	90.59 ± 8.88	Non-toxic
Tap water	5	-15.05 ± 3.53	Growth stimulation	89.03 ± 9.08	Non-toxic	106.55 ± 9.45	Growth stimulation (5-75%)
	10	13.58 ± 2.64	Non – toxic	89.30 ± 7.89	Non-toxic	118.55 ± 10.92	
	25	-28.51 ± 5.31	Growth stimulation	88.23 ± 7.96	Non-toxic	131.36 ± 9.88	
	50	-10.70 ± 3.91	Growth simulation	128.88 ± 10.67	Growth stimulation	119.95 ± 10.28	
	75	-85.03 ± 8.21	Growth stimulation	108.03 ± 9.87	Growth stimulation	126.07 ± 8.28	
	100	39.77 ± 3.71	Low – toxic	86.62 ± 8.75	Non-toxic	90.59 ± 8.88	Non-toxic
Rainwater	5	23.12 ± 9.14	Non/low – toxic	111.52 ± 8.78	Growth stimulation	130.13 ± 10.16	Growth stimulation (5-75%)
	10	-8.76 ± 7.09	Growth stimulation	92.79 ± 6.68	Non-toxic	124.97 ± 12.33	
	25	1.60 ± 7.47	Non – toxic/Growth simulation	92.41 ± 6.96	Non-toxic	136.74 ± 8.23	
	50	7.64 ± 4.28	Non – toxic	106.09 ± 7.56	Growth stimulation	140.20 ± 5.64	
	75	-0.20 ± 6.45	Non – toxic/Growth stimulation	96.92 ± 8.78	Non-toxic	127.89 ± 6.87	
	100	39.77 ± 3.71	Low – toxic	86.62 ± 8.75	Non - toxic	90.59 ± 8.88	Non - toxic

5. Conclusions

The use of washings from swimming pool facilities for the maintenance of greenery is an opportunity to reduce the consumption of tap water. Due to the presence of total suspended solids and chlorine remaining after the disinfection process, it is necessary to apply simple measures to improve their quality - sedimentation and de-chlorination. However, the presence of aluminum with prolonged use of washings can negatively affect both plants and soil. Therefore, the use of washings as the only source of plant nutrition may entail the risk of toxic effects.

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